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14. ABSTRACT

Sustained unilateral hand clenching alters perceptual processing and affective/motivational state, presumed to reflect increased hemispheric activity contralateral to the side of motor movement. Data from electroencephalographic and imaging studies are contradictory regarding the relationship between sustained hand clenching and brain activity. To investigate relationships between brain activity, sustained unilateral hand clenching, and changes in affect and perceptual processing, frontal hemispheric activity was measured via

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Report Title

Final Report: Investigation of a Neurocognitive Biomarker and of Methods to Mitigate Biases in Cognitive/Perceptual/Emotional Processing

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Sustained unilateral hand clenching alters perceptual processing and affective/motivational state, presumed to reflect increased hemispheric activity contralateral to the side of motor movement. Data from electroencephalographic and imaging studies are contradictory regarding the relationship between sustained hand clenching and brain activity. To investigate relationships between brain activity, sustained unilateral hand clenching, and changes in affect and perceptual processing, frontal hemispheric activity was measured via Functional Near-Infrared Spectroscopy (fNIRS), using derived O2Hb prior to, during, and post-sustained unilateral hand clench. Participants' mood and spatial perception were recorded pre- and post-clenching. Sustained unilateral hand clenching altered brain activity and mood, but not spatial perception. O2Hb increased bilaterally following sustained unilateral hand clenching, relative to baseline, regardless of hand. Sustained unilateral hand clenching resulted in greater ipsilateral, compared with contralateral, O2Hb. An interaction between side of hand clench and change in mood was in the direction predicted by theories of hemispheric lateralization of emotion: Following left hand clenching, individuals became more affectively negative, and following right hand clenching, they became more affectively positive. The only relationship between O2Hb and behavioral measures was a positive correlation between left hemisphere O2Hb during hand clenching, and post-clench nervousness.

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Sub Contractors (DD882)

Inventions (DD882)

Scientific Progress

See Attachment

Technology Transfer

FINAL PROGRESS REPORT (FPR)

Statement of problem studied/ summary of the research projects on which the equipment has been used, including support of the research work described in the proposal: Sustained unilateral hand clenching alters perceptual processing and affective/motivational state, with these alterations presumed to reflect increased hemispheric activity contralateral to the side of motor movement. By increasing the activity of one versus the other hemi-cortex, sustained unilateral hand clenching is thought to result in a processing bias toward the more activated, contralateral, hemisphere, and a concomitant change in behavior (for example, see Beckman, Gröpel, & Ehrlenspiel, 2013; Goldstein, Revivo, Kreitler & Metuki, 2010; Harmon-Jones, 2006; Peterson, Gravens, & Harmon-Jones, 2011; Peterson, Shackman, & Harmon-Jones, 2008; Propper, McGraw, Brunyé, & Weiss, 2013; Schiff & Lamon, 1994; Schiff & Truchon, 1993; Schiff, Guirguis, Kenwood, & Herman, 1998)

Goldstein, Revivo, Kreitler, and Metuki (2010), using a common method for inducing sustained unilateral hand clenching, had participants clench either their right or left hand as hard as possible for 45 seconds, followed by a resting period of 15 seconds, with this sequence of clench-rest being repeated four times. Participants then performed a line bisection task, considered a measure of hemispheric activation and perceptual attention, and the Remote Associates Task (RAT, Mednick, 1968). Sustained unilateral hand clenching of the left hand resulted in increased leftward line bisection bias, suggesting increased right hemisphere activity. Additionally, such clenching resulted in superior RAT performance, with this effect suggested to reflect the increased access to the wider semantic network of the right hemisphere.

Several studies have demonstrated changes in emotional state following sustained unilateral hand clenching. For example, Schiff and Lamon (1994) found that the emotional tone of stories was more negative following left (right hemisphere activation), compared to right (left hemisphere activation), sustained unilateral hand clenching. Similarly, Harmon-Jones (2006) reported increased approach motivational affect following sustained right unilateral hand clenching (left hemisphere activation). The effects of hand clenching on emotional/motivational state are in accord with, and have been interpreted as fitting, theories of cerebral lateralization of emotion/motivation, with the left hemisphere being approach/positive, and the right hemisphere withdrawal/negative (e.g.; Davidson, 2002).

Despite the behavioral evidence suggesting that sustained unilateral hand clenching alters contralateral cerebral function, thereby inducing a processing bias toward the contralateral hemisphere, the neural substrates underlying changes in behavior following sustained motor movements are not clear. Electroencephalographic (EEG) studies of sustained unilateral hand clenching seem to support the hypothesis that these motor movements increase contralateral frontal hemispheric activity, as demonstrated by decreased EEG power in the contralateral hemisphere during clenching (e.g.: Harmon-Jones, 2006; Peterson, Gravens, & Harmon-Jones, 2011; Peterson, Shackman, & Harmon-Jones, 2008). However, examinations of cortical activity using imaging techniques such as Functional Magnetic Resonance Imaging (fMRI) and Functional Near-Infrared Spectroscopy (fNIRS) demonstrate both contralateral and ipsilateral brain activity during or following sustained unilateral hand motor movements (e.g.: Derosière, Alexandre, Bourdillon, Mandrick, Ward, & Perrey, 2013) For example, Shibuya, Kuboyama, and Tanaka (2014), and Shibuya, Sadamoto, Sato, Moriyama, and Iwadate (2008) both using fNIRS, demonstrated activation of both contralateral and ipsilateral motor areas during performance of sustained unimanual (finger) force production. Particularly relevant, Derosière et al. (2013), using fNIRS, examined frontal cortical areas during a sustained unilateral handgrip task. At high levels of force generation, the ipsilateral frontal lobe demonstrated greater activation than that of the contralateral frontal lobe. Given that currently used methods for generating contralateral hemispheric activity to induce changes in behavior require participants to clench their hands 'as hard as they can' for a sustained period of time (usually 45 seconds, repeated between 2 to 4 times), and given that stronger clenching is associated with increased ipsilateral relative to contralateral frontal lobe activity (e.g.: Derosière, Alexandre, Bourdillon, Mandrick, Ward, & Perrey, 2013), the relationship between changes in behavior induced by sustained unilateral hand clenching, and the neuronal processes responsible for such changes following hand clenching, is unclear.

The purpose of the research was to examine motor movement-induced changes in perception and affective/motivational state, and their relationship to brain activity in the prefrontal cortex as measured via fNIRS. Line bisection was chosen because performance has previously been shown to change following sustained unilateral hand clenching (e.g.: Goldstein, Revivo, Kreitler, & Metuki, 2010), with left hand clenching resulting in leftward bias, presumed to indicate increased right hemisphere activity. Emotion was also assessed because changes in mood following sustained unilateral hand clenching have also been reported (e.g.: Harmon-Jones, 2006; Schiff & Lamon, 1994). These emotional changes have been consistent with theories of lateralization of emotional/motivation state (e.g.; Davidson, 2002), such that unilateral clenching of the left hand, presumed to activate the right hemisphere, results in negative or withdrawal motivations, and unilateral clenching of the right hand, presumably via activation of the left hemisphere, results in positive or approach motivations. FNIRS was used to assess prefrontal cortical activity following sustained unilateral hand clenching, and the relationships between brain oxygenation, mood, and line bisection performance were examined. Specifically, In order to investigate the relationship between brain activity, sustained unilateral hand clenching, and changes in affect and perceptual processing, frontal hemispheric activity was measured via Functional Near-Infrared Spectroscopy (fNIRS), using derived O_2Hb prior to, during, and post-sustained unilateral hand clench. Participants' mood (via the Brief Mood Introspection Scale) and spatial perception (via Line Bisection) were recorded pre- and post-clenching. Additionally, tympanic membrane temperature (TMT), a potential indicator of hemispheric activity (see Propper & Brunyé, 2013), was also investigated. Because TMT may indicate hemispheric activity, and therefore has the potential to be a marker for cognitive performance, linking TMT with other neurophysiological markers of hemispheric activity (e.g. fNIRS-derived O_2Hb) would support the utility of this simple measure.

<u>Summary of most important results:</u> Sustained unilateral hand clenching altered brain activity and mood, but not spatial perception. Results revealed increased O_2Hb bilaterally following sustained unilateral hand clenching, relative to baseline, regardless of hand. In agreement with previous fNIRS studies, sustained unilateral hand clenching resulted in greater ipsilateral, compared with contralateral, O_2Hb. (See Appendix A for Figures of relationships between side of unilateral hand clench and O_2Hb.) An interaction between side of hand clench and change in mood was in the direction predicted by theories of hemispheric lateralization of emotion: Following left hand clenching, individuals became more affectively negative, and following right hand clenching, they became more affectively positive. The only relationship between O_2Hb and behavioral measures was a positive correlation between left hemisphere O_2Hb during hand clenching, and post-clench nervousness. No relationship between any measure or manipulation

with TMT was found. Result indicate sustained unilateral hand clenching alters hemispheric activity as well as affective/motivational state. However, the underlying relationship between brain activity and mood is still unclear.

Summary of future research on which the equipment will be used: Future research will investigate variations in muscle strength using EMG in conjunction with behavioral, cognitive and fNIRS monitoring to determine if hand clenching strength is related specifically to changes associated with unilateral hand clenching. Other work will attempt to replicate fNIRS findings of primarily ipsilateral hemispheric activity subsequent to unilateral hand clenching using EEG. Additional research explicitly varying strength of hand clenching (for example, by having participants clench 50% of effort) in examinations using fNIRS and behavioral/cognitive/perceptual measures will further shed light on the interrelationships between hemispheric activity changes as a result of sustained unilateral hand clenching and changes in emotion, cognition, and perception.

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APPENDIX A

Fig. 3a-3d fNIRSoft-derived frontal-view topograph, with a 190 threshold for visualization. ‘Warmer’ colors (i.e.: red, orange, yellow) denote increasing O_2Hb

3a O_2Hb in the left and right hemispheres during 30 seconds of the second left hand clenching condition

Fig. 3b O_2Hb in the left and right hemispheres during the 20 seconds post-clenching in the left hand clenching condition

Fig. 3c O_2Hb in the left and right hemispheres during 30 seconds of the second right hand clenching condition

Fig. 3d O_2Hb in the left and right hemispheres during the 20 seconds post-clenching in the right hand clenching condition

Figure 3a

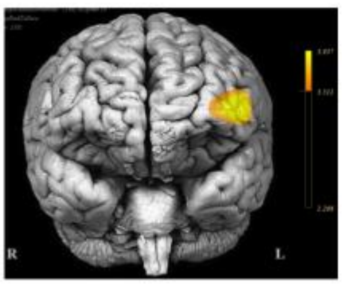

Figure 3b

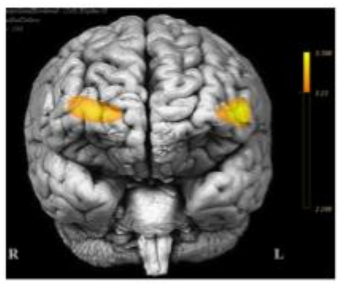

Figure 3c

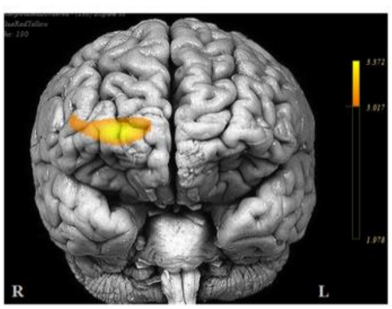

Figure 3d